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A PIONEER IN APPLIED SCIENCE.

Collected Papers in Physics and Engineering. By Prof. James Thomson, F.R.S. Selected and arranged with unpublished material and brief annotations by Sir Joseph Larmor, Sec. R.S., and James Thomson. Pp. civ+484. (Cambridge: University Press, 1912.) Price 15*s.* net.)

WHEN Sir Joseph Larmor edited the scientific papers of Lord Kelvin and Prof. Fitzgerald he did work which nobody else could have done so perfectly; his time, however valuable, was spent to advantage. The editing of these papers of Lord Kelvin's brother might have been undertaken by many others, but now that the excellent result is before us we cannot regret it, and we must confess that we did not expect to find in the editor such a perfect sympathy with James Thomson's methods of study. He shares with Prof. Thomson's son the honour and credit of this publication. The book begins with about a hundred pages of biography and comment upon Thomson's works—excellent reading. Then we have 153 pages of papers relating to fluid motion, dating from 1852 to the Bakerian lecture of 1892; nearly eighty pages on congelation and liquefaction from 1849 to 1888; forty pages on the continuity of states in matter from 1869 to 1873; seventy pages on dynamics and elasticity from 1848 to 1887; and about eighty pages on geological and miscellaneous subjects from 1848 to 1892.

James Thomson was very exact in his use of language and in his ways of thinking. Even although in some of our studies we are quite exact, most of us are quite slipshod about other things that we think we know. If it were necessary to give examples the reader might be referred to paper 14 of this collection. Thomson there refers to the usual methods of study of the flow of water. He says: "The theoretical views so arrived at and very generally promulgated are in reality only utterly false theories based on suppositions of the flow of the water taking place in ways which are kinematically and dynamically impossible, and are at variance with observed facts of the flow, and even at variance with the facts as put forward by the advancers of those theories." After giving some examples, he says: "Now this method is pervaded by false conceptions and is thoroughly unscientific." Although Thomson constructed his famous turbine sixty years ago and put in simple language the principles on which nearly all modern water and steam turbines are now being constructed, these papers of his are so little known that nearly all books on hydraulics are still pervaded with the old false conceptions and unscientific methods.

He was free from the common fault of self-deception. There is no vagueness in any of his explanations of phenomena. When he explains such a thing as the tears of strong wine and refers to surface tension he is as exact as Prof. Boys or Lord Rayleigh, and he demands from his reader the same carefulness. When he is not perfectly sure of a thing he tells you so frankly. The results of Thomson's thought in so far as physics is concerned are known to all of us; they are to be found in all text-books; I wish we could say the same about his work in engineering. But both physicist and engineer will get much education in reading the original papers. They will come in contact with a true scientific mind, absolutely honest, intensely observant, afraid of self-deception, concentrative, persistent and tireless. I have no hesitation in saying that the hydraulic engineer who has not read these papers has a great deal to unlearn and learn.

Only the very simplest mathematical or scientific knowledge is needed by the reader, but he must have common sense and humour and the same inclination to laugh at pretentious, ignorant notions as the author himself. I think myself that in a few cases Thomson ought to have worked with higher mathematics. For example: water being supposed to be frictionless and to flow from two similar vessels with similar and similarly placed orifices, he thought it necessary to prove that the lines of flow are similar. If this is so, it is evident that if l and L are the dimensions, p and P the pressures, v and V the velocities at similar places, then $P/p = L/l$ and $V/v = \sqrt{L/l}$. His proof of the similarity is ingenious. Applied to the case of vessels moving through water it is Froude's law, but in this case, unlike Thomson's own, viscosity enters into the real phenomena in an all-important way, and the assumption that the proposition has been proved is very dangerous. Thomson used his proposition in getting a rational formula for the measurement of water by his triangular notch, and in proving that the empirical formula of Dr. Francis for rectangular notches is really a rational formula. It is curious that it should be necessary to tell engineers that the Francis formula is correct and that the usual formulæ of the text-books are quite incorrect.

Now that long proof given by Thomson in his 1876 paper (given by him to students in his classes for fifteen years previously) seems to me unnecessary. In one of his vessels A the flow is natural, and in the other B he guides the flow in stream

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lines similar to those of A; he shows that there are no forces tending to deform the guides of B, and if we imagine them to disappear the flow is unchanged and remains similar to the flow in A. But since he proves so much, he ought to prove that there is no other way in which the flow can occur in B, and I am afraid that this cannot be done except by Kirchoff's use of higher mathematics. Indeed, Kelvin showed that there might be two answers to all such problems, one of them being unstable.

The first of these fluid motion papers (1852) deals with the free vortex. The example to which he most frequently referred his students was that of water leaving a basin by a central hole. The nearly circular motion of every particle is such that the speed is inversely proportional to distance from the axis, and he satisfied himself that our simple theory as to pressure, circular speed v, and height was correct. But he noticed that particles of dust on the lower surface of the basin moved in towards the hole nearly radially; he arrived at the conclusion that surface friction destroyed v, and therefore destroyed the centrifugal force, and therefore destroyed the balance of pressures, and therefore created a radial flow. This simple principle gave the key to the atmospheric phenomena of great forest fires; it enabled him to explain what occurs at river bends and why a river through alluvial ground tends to become more and more crooked; it enabled him to explain the phenomena of cyclones, and, most important of all, it enabled him in 1857 to give his simple explanation of what had puzzled many clever scientific men for two hundred years, the grand currents of atmospheric circulation. That short paper is easy to understand. The Bakerian lecture of the Royal Society with the same title, delivered in 1892 two months before his death, added nothing to that simple explanation, then thirty-five years old, but in it he gave at some length the history of the problem.

Hadley, in 1735, explained the trade winds in latitudes 30 S. to 30 N., but in all the numerous writings by distinguished men before and after Hadley until 1857 there was only slipshod reasoning and no explanation of the prevailing S.W. winds north of latitude 30 N. There is a whirl of the atmosphere there from the west which would produce no northerly flow of the air, only that there is friction against the earth; this diminishes the speed of the air and upsets the balance of pressures, producing a northerly flow close to the earth's surface—exactly the basin phenomenon! His proof, in 1849, that pressure lowers the melting point of ice consists in subjecting a mixture of ice and water to a Carnot cycle. He assumes with Carnot that no heat disappears when work is done, but he states quite clearly, as nobody else had ever done, what the third part of the cycle would be if Carnot were wrong and if less heat were given out than what had been received.

Using Regnault's experimental results for steam, Lord Kelvin had in 1848 calculated the value of Carnot's function, and James Thomson used the result, which was this:—"We find that the quantity of work developed by one of the same thermal units descending through one degree about the freezing-point is 4·97 foot-pounds." This enables him to find that the lowering of the melting-point is 0·00000355 p where p is the increase of pressure in pounds per square foot. This paper and Kelvin's paper and their connection with the vexed question, "Who discovered the second law?" are exceedingly interesting. Kelvin's paper of 1851 first established the second law on a logical basis irrespective of assumed properties of matter, and Kelvin was too generous in giving credit to Clausius and, indeed, to Rankine also. But these four men and Joule himself were all very close to the discovery in the three years 1848 to 1851. I know of no more interesting reading than what I find in Prof. Silvanus Thompson's life of Lord Kelvin during these years. No one of Plutarch's heroes "played the game" more nobly than the Thomsons.

James Thomson reasoned out from the above principle the cause of the flow of glaciers and the plasticity of ice and other curious ice phenomena, as well as the influence of stress on crystallisation generally, in a series of papers and letters until 1889. In 1862 he had made a model of a surface showing how p, v and t for carbonic acid vary, and had thought of conditions of instability. Dr. Andrews's Bakerian lecture of the Royal Society in 1869 caused him to revert to his previous study of the discontinuities of his surface, to complete his model and to write papers of 1871 on the abrupt changes at boiling and condensing. He reasoned out the existence of the triple point for ice, water and steam in 1872 and 1873 in the same way as that of his 1849 paper on ice. The one p, t curve for saturated steam drawn on copper by Regnault is really two curves the slopes of which at 0° C. are not the same, being in the ratio dp/dt for ice-steam $\div$ dp/dt for water-steam $= 1{\cdot}13$. These matters are familiar to all readers of Maxwell's book on heat, but the student will be interested in the letters and notes from 1862 which describe how Thomson was led to his results. He used to tell his students, with some glee, how his eye detected in Regnault's curve the discontinuity at 0° C. which nobody had noticed before.

His valuable papers on the strength and elas-

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ticity of materials, the theory of springs, safety and dangers in structures and the testing of structures, on units, on dimensional equations, on absolute motion, on fatigue of materials are less well known, but students who read them will get a clear insight into subjects on which text-book reasoning is sometimes rather slipshod. His paper on the parallel roads of Lochaber is acknowledged to have cleared up a great geological puzzle. His paper on prismatic structure in basaltic rocks cleared up the Giant's Causeway puzzle.

In his paper of 1872 on atmospheric refraction of inclined rays and on the path of a level ray he solved another important problem. His integrating machine is now in use for tide-calculation. There are many papers on subjects of general interest to which I cannot refer because I have no space. Suffice it to say that on every subject about which he wrote he threw a new light, he gave fresh ideas and he started students on new lines of thought. In reading one of his papers we instinctively feel sure that he has given long and careful consideration to the matter and has looked at it from many points of view; consequently he has exact and clear ideas, and he is able to state them in simple language, so that we at once accept his conclusions as correct.

JOHN PERRY.

TABLES OF THE WEIGHT OF AIR.

Tabellen der Luftgewichte γ_t^b, *der Druckäquivalente* β_t^b *und der Gravitation* g.

Tables des poids de l'air γ_t^b, *des equivalents barométriques* β_t^b *et de la gravité* g.

Tables of the Weight of Air γ_t^b, *of the Air-Pressure Equivalents* β_t^b *and of the Gravity* g. By Dr. S. Riefler. Pp. iv+101. (Berlin: Julius Springer, 1912.) Price 6 marks.

IN rough experiments, the density or the weight of the air may often be ignored; generally, however, it is allowed for with more or less completeness. But when it is desired, as in the author's work, to make a precise determination, so precise that the effect of moisture in reducing it, or carbonic acid gas in increasing it, must not be ignored, and when the local value of g has to be allowed for, then the investigator may find the calculation to be unduly tedious.

The author of these admirable tables has been brought face to face with the difficulty in connection with the disturbing effect of the density of the surrounding air on the period of the pendulum of the astronomical clock. For instance, the rate of such a pendulum is changed by 1/100 second per day, so he states, by a variation in weight of one milligram per litre in the air surrounding the pendulum. He has, therefore, calculated a series of tables, where they were not already in existence, whereby all the data required can be found with the maximum of directness and accuracy and the minimum of trouble. Every table has the formula on which it is based printed at the head, and a clear statement of the whole problem is printed in three parallel columns in German, French and English. In only one case is this departed from, where the names of the countries in which a large number of stations are situated for which g has been determined are printed in English only, "on account of the extended use of this language"—a compliment which an English paper should acknowledge.

The most important of the tables is calculated for every 10 mm. of barometric height from 380 to 680 mm., and then for every mm. up to 790 mm., and for every degree of temperature from -1° C. to $+36^\circ$ C. For all these conditions the weight of a litre of air free from CO_2, but both dry and half saturated with moisture, is calculated on the basis that at Paris the weight of dry air free from moisture and CO_2 is, under standard conditions, 1293·21 mg. Alongside the figure giving the weight is another, called by the author "the pressure equivalent of temperature," which shows the change in pressure in mm. of mercury due to a change of 1° C. in temperature. It is interesting to notice that this, in the case of half-saturated air at 760 mm., has a minimum value at about 17° C.

It would require more space than is available to discuss the tables fully. It is sufficient to say that the printing, the paper and the arrangement are all admirable, and that these tables should be found in every laboratory where exact work is done.

C. V. B.

ANTHROPOLOGY AND ARCHÆOLOGY.

(1) *The Annual of the British School at Athens.* No. xvii. Session 1910–11. Pp. liv+355+xxi plates. (London: Macmillan and Co., Ltd., 1912.) Price 25*s.* net.

(2) *The Cochin Tribes and Castes.* By L. K. Anantha K. Iyer. Vol. ii. Pp. xxiii+504. (Madras: Higginbotham and Co.; London: Luzac and Co., 1912.)

(3) *The Origin of Civilisation and the Primitive Condition of Man.* Mental and Social Condition of Savages. By the Right Hon. Lord Avebury. 7th edition. Pp. xxviii+454. (London: Longmans, Green and Co., 1912.) Price 7*s.* 6*d.* net.

(4) *Notes and Queries on Anthropology.* Edited

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